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24 March 2022

Project/File: 310003282

Michael Duindam
Palmerston North City Council
32 The Square
Palmerston North 4410

Dear Michael,

1 Introduction

The undersigned, Eleni Gkeli, is a Senior Principal Engineering Geologist with Stantec New Zealand (Stantec). Eleni holds a BSc (4 years duration of studies) in Geology from the National University of Athens, Greece, and two MSc, in Rock Mechanics and Foundation Engineering from the University of Newcastle Upon Tyne, UK, and in Tunnel Design and Construction from the National Technical University of Athens, Greece.

Eleni has over 25 years of experience as a consultant in the Geotechnical Engineering profession in infrastructure projects internationally and in New Zealand. Eleni moved to New Zealand in 2012 and has worked for Opus (now WSP), Coffey and Stantec, undertaking geotechnical investigations, geotechnical assessments, natural hazards assessments etc. She has carried out numerous reviews of resource consent applications, e.g., for Hutt City Council and has worked for land development assessments for Kainga Ora, land damage assessments for the Earthquake Commission, etc.

The undersigned, Ioannis Antonopoulos, is a Technical Director with Stantec. Ioannis holds a BSc (4 years duration of studies) in Geology from the National University of Athens Greece, a MSc in Engineering Geology from the Imperial College, London, UK, and a Washington Accord Equivalence from Engineering NZ. Ioannis has over 27 years of experience as a consultant in the Geotechnical Engineering profession in infrastructure projects internationally and New Zealand. Ioannis moved to New Zealand in 2012 and has worked for Opus (now WSP), Coffey and Stantec, undertaking geotechnical investigations and design.

2 Background

Flygers Investment Group Ltd (the Applicant) have submitted a request for Private Plan Change (PPC) to Palmerston North City Council (PNCC), which involves rezoning of approximately 12.9 hectares of land from Rural Zone to Residential Zone and an area of 10 hectares of land adjacent to that from Rural to Recreation Zone and establish Whiskey Creek Residential Area.

The area is located at the northern urban edge of the city at 611 Rangitikei Line and is adjacent to existing residential land at Meadowbrook Drive and Benmore Avenue.

The request for Whiskey Creek Residential Area was subject to public consultation which was completed on Tuesday 9 November 2022.

This letter report presents our expert's opinion on the following:

- How the effects of natural hazards and respective policies under Sections 7-3-3.1 and 22.1 – 2 -3 of the District Plan are addressed by the Applicant.
- The issues raised from public submissions as part of the consultations related to natural hazards of geological, geotechnical and earthquake nature.

3 Documents reviewed

The following documents included in the PPC Application were reviewed:

1. "Geotechnical Assessment Proposed Plan Change Rangitikei Line and Flygers Line, Palmerston North" Riley Consultants Ltd., 22 February 2019.
2. "Lateral Spreading Assessment, Rangitikei Line & Flygers Line, Palmerston North", Totla Ground Engineering, 19 November 2020.

4 Geotechnical issues in the public submissions

The issues raised during public consultation related to geotechnical natural hazards are shown in Table 1.

Table 1: Geotechnical hazard effects raised in the public consultation

No	Submission point	Position	Submission number
1	Flooding risk, management of stormwater and drainage of the site, effects on adjacent properties and infrastructure	Opposed	SO-1, SO-2, SO-3, SO-5, SO-7, SO-9, SO-10, SO-11, SO-12, SO-13, SO-15, SO-16, SO-26
2	Flooding risk, management of stormwater and drainage of the site, effects on adjacent properties and infrastructure	Conditional support	SO-8, SO-17, SO25
3	Liquefaction risk	Opposed	SO-15, SO-20, SO-22
4	Liquefaction risk	Conditional Support	SO-8, SO-18

Our comments on the issues raised in the public consultation are provided below:

4.1 Flooding Risk

The flooding risk, management of stormwater and drainage of the site to adjacent properties and infrastructure is not part of the scope and the expertise of this review. We recommend that a separate review of these matters is conducted by the appropriate specialist(s).

Comment on how the flooding risk affects the geotechnical assessment and design of the development in terms of ground settlements, earthworks design etc. is provided in Section 5.5.

Reference: **Stantec SFA dated 01/03/2022**

4.2 Liquefaction Risk

The comments around the liquefaction risk are largely related to the review of the Geotechnical Assessment Report (Riley, 2019) and the Lateral Spreading Assessment Report (Total Ground Engineering, 2020). These comments raised in the public consultation are addressed in Section 5.4 of this report.

5 Geotechnical natural hazards under plan provisions

The following geotechnical natural hazards should be addressed in the request for PPC for the proposed residential development based on the PNCC District Plan policies:

1. Ground shaking.
2. Surface Fault rupture.
3. Liquefaction and lateral spreading.
4. Land stability.
5. Flooding and how this can affect the development from a geotechnical point of view.

Comment on the effect of the above hazards and risks to the proposed development and the extent to which these are addressed in the proposal is presented in the following sections.

5.1 Ground shaking

We refer to the Geotechnical Assessment report by Riley Consultants, dated 22 February 2019, referred to as the Geotechnical Assessment report.

The seismic hazard for the site, to be used in the liquefaction and lateral spreading assessments and geotechnical design, has been estimated based on the methodology included in the Geotechnical Earthquake Engineering Guidelines, published in 2016 jointly by the Ministry of Business Innovation and Employment and the New Zealand Geotechnical Society, also known as the Geotechnical Modules, (MBIE / NZGS, 2016). The Module used for assessing the seismic hazard in the Geotechnical Assessment report is Module 1, Version 0 (MBIE/NZGS, 2016), herein referred to as Module 1 v0.

NZGS and MBIE have revised those Guidelines in November 2021. The most up to date information to be used for the assessment of the seismic hazard for geotechnical assessments and designs of new buildings is currently included in Module 1 Version 1 (MBIE/NZGS, 2021), herein referred to as Module 1 v1.

The seismic hazard for six (6) areas across New Zealand has been updated in Module 1 v1, including the hazard for Palmerston North. The seismic hazard parameters, i.e., peak ground acceleration (α_{max}) and earthquake magnitude (M_w) to be used for a geotechnical design that follows Method 1 of Module 1 v1 have been increased, compared to those provided in the previous version Module 1 v0 and the NZTA Waka Kotahi Bridge Manual (2018).

Reference: **Stantec SFA dated 01/03/2022**

The Riley Consultants Ltd. (2019) report classified the site according to NZS 1170.5:2004 as Class C and possibly Class D, and conservatively use Class D for their assessments. It is important to note the below differences between the two classes:

- According to Module 1 v0, Method 1, Class C relates to a peak horizontal ground acceleration, α_{max}, which is 1.33 times higher than Class D.
- According to Module 1 v1, Method 1, the α_{max} values provided are soil class independent.
- For structural design, the elastic site spectra for Class D have both larger and longer amplification plateau, i.e., amplification factor 3 for periods between 0.1 sec and 0.5 sec (Class D), vs. amplification factor 2.93 for periods between 0.1 sec and 0.3 sec (Class C).

The updated seismic hazard parameters, and the Class C vs. D differences, for Palmerston North for the Serviceability (SLS) and Ultimate (ULS) Limit States are shown in Table 2. The corresponding characteristic earthquake magnitude is 6.4 for the SLS Criteria 1 and 7.5 for all other cases.

Table 2: Updated seismic hazard for Palmerston North since November 2021 (Module 1 v1)

Importance Level	**SLS** Criteria 1 (1-in-25 year)			ULS **(1-in-500 year)**		
IL2, 50 Year Design Life	**Module 1 v0 (2016)**		**Module 1 v1 (2021)**	**Module 1 v0 (2016)**		**Module 1 v1 (2021)**
	Class D	**Class C**	**Class Independent**	**Class D**	**Class C**	**Class Independent**
	0.09 g	0.12 g	0.13 g	0.34 g	0.45 g	0.55 g

The use of the seismic hazard included in Module 1 v0 in the Geotechnical Assessment report for the Whiskey Creek Development by the Applicant is reasonable since the report has been completed in February 2019, before the revision of Module 1 and update of the hazard.

However, it should be noted that:

- The liquefaction and lateral spreading potential at the site and the associated settlements are expected to be higher than currently assessed (see also comments in Section 5.4)
- The updated hazard should be used for the geotechnical assessment and designs in the future for this development should it proceed to the next stages of consenting.
- A more rigorous soil classification is carried to out to define the soil class per NZS 1170.5:2004 for structural design.

We recommend that a consent condition is included to ensure that the liquefaction assessment is updated with the most current seismic hazard at the time of the next stage of design and that the foundation solutions currently proposed are updated accordingly.

5.2 Surface fault rupture

Numerous active faults and potentially seismogenic structures are mapped within a 40 km radius of Palmerston North City (Begg & Johnston 2000, Lee & Begg 2002; Townsend et al. 2008; GNS Science Active faults database). Each of these has the potential to generate felt intensities of MM7 or more in the Palmerston North City area.

In terms of ground shaking, seismogenic sources, known and unknown, have been included in the seismic hazard specified in Module 1 Version 1 discussed in Section 5.1 above.

Assessment of the possibility that active faults are present adjacent to or crossing the site has not been included in the Geotechnical Assessment report. The Applicant should provide an assessment and confirm that no fault lines are crossing or adjacent to the proposed development site and the level of risk of surface fault rupture or the site.

5.3 Land stability

The land proposed for development is generally flat, so we agree with the Applicant's assessment that the risk of land stability, under static and seismic conditions is considered negligible.

The land deformations (settlements) due to the loading of the proposed earthworks and structures under static conditions will need to be assessed in the detailed design stage of the development, should it proceed.

The seismic land deformations induced due to liquefaction and lateral spreading have been assessed separately in the Application and are discussed in the following sections.

5.4 Liquefaction and Lateral Spreading

5.4.1 RILEY CONSULTANTS LTD. (2019)

Riley Consultants Ltd (2019) identified that potentially liquefiable materials lie within the upper 6 m bgl (bgl = below ground level) of the soil profile, comprising discrete layers of loose to medium dense sandy silt, or silty sand and that the dense to very dense gravels encountered below 6 m bgl depth are not likely to liquefy.

The estimated free field settlements range between 17 mm and 119 mm with an average of 71 mm, and the ground performance is expected to be consistent with TC2 as per the MBIE Guidance. Lateral spreading is not explicitly calculated, however, based on experience from Christchurch the below three options for foundations and/or ground improvement are given.

1. A ground improvement solution that allows for a TC2 type foundation. However, ground improvement options are not elaborated.

2. Utilise TC2 type foundations with appropriate setbacks without ground improvement. However, the setback is not explicitly defined.

3. Utilise TC3 type foundations with a lesser setback than Option 2.

Riley Consultants Ltd. conclude with the recommendation that further investigations surrounding stream banks and other free faces are carried out to gain a more accurate prediction of lateral spreading displacements for this site and further develop options to mitigate the hazard.

5.4.2 TOTAL GROUND ENGINEERING (2020)

Total Ground Engineering (2020) was engaged to carry out supplementary site investigations and analyses of lateral spreading. They concur with the liquefaction analysis methodology and results obtained by Riley and generally concur with their conclusions. In addition, they have calculated the lateral spreading magnitudes using limit equilibrium analyses and recommend the below options.

1. To set out a building exclusion line, 55 m from the limit of earthworks.
2. To widen the overland flow channel to a minimum width of 55 m from the flood protection line.
3. To construct an 8 m wide band of ground improvement which would isolate the proposed subdivision from the lateral spreading by acting as a shear key.

For the third option they suggest three construction methods: (a) to excavate and replace the sediments with river gravels, (b) dynamic compaction, (c) stone columns. However, neither of these options is further quantified.

5.4.3 OUR OPINION

We concur with the identified risks for liquefaction and lateral spreading. However, based on the change of seismic demands per Module 1 v1, and the uncertainty of soil class per NZS 1170.5:2004, we expect that the green field liquefaction induced settlements and lateral spreading magnitude and extend should be greater than those already reported. The soil-foundation-structure interaction, by including the structural geometry and loads, should also be assessed to quantify the risk and to optimise the selection and design of an economical ground improvement and/or foundation solution.

Furthermore, we recommend that a more rigorous assessment is carried out, as part of the Resource Consent phase, to ensure that the liquefaction and lateral spreading assessment is updated with the most current seismic hazard at the time of the next stage of design and that the foundation solutions currently proposed are updated accordingly.

5.5 Flooding and Earthworks

The site proposed for development is a flood-prone area based on the PNCC District Plan.

Due to the flooding potential of the site and to increase the area available for residential development, earthworks have been proposed on the eastern side of the site to raise the residential building platforms above the flood level.

The area of the earthworks is approximately 10 hectares in size, with 23,000m^3 of material cut from beside Whiskey Creek. This material is to be used to raise the fill area to be above the flood level.

The review of the flood model prepared to assess the impact of the overall development, the proposed management of the Mangaone Stream and Whiskey Creek and the effects of the proposed earthworks

Reference: **Stantec SFA dated 01/03/2022**

on the drainage pattern of the wider area in a flood event, is outside the scope and expertise of this review and will be covered separately.

From a geotechnical point of view, we note the following to be taken into account in the resource consent stage of the earthworks, to comply with PNCC Engineering Standards for Land Development (October 2021):

- The proposed cuts along Whiskey Creek should be appropriately designed not to adversely affect the stability of the adjacent and nearby land in all loading conditions, i.e., static, seismic and flooding. Appropriate protection measures should be implemented for slope surface erosion and scour due to flooding.

- The fill areas should be designed for pore water pressure changes caused by high-level water table and rapid drawdown conditions. Appropriate slope surface erosion and scour protection measures should be also implemented.

Ngā mihi nui,

STANTEC NEW ZEALAND

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